THE PRODUCTION OF STRATIGRAPHICAL RANGE-DIAGRAMS BY AUTOMATIC METHODS

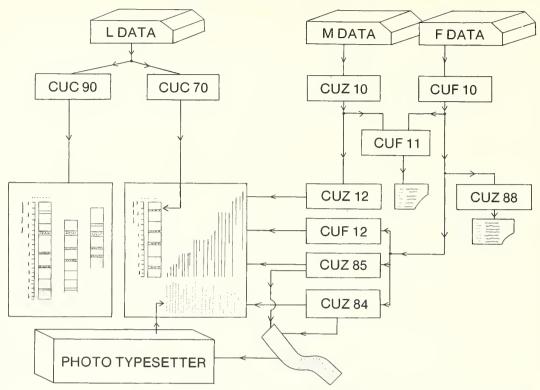
by IAN E. PENN

ABSTRACT. A package of computer programs has been developed on the Institute of Geological Sciences' IBM 1130 computer which, after accepting and sorting data submitted on a simple input format, draws stratigraphical range and abundance diagrams to any desired scale. The range-diagrams may be of first occurrence; last occurrence; taxonomic order; any specified order including sorting within sub-groups. An ornamented lithological plot is accurately aligned and a correctly ordered, punctuated and type-set list of fossil names may be produced from companion dictionaries. The resultant diagram is suitable for direct publication. It is estimated that, the programs having been installed, the computer method produces diagrams in one-tenth of the time and at one-quarter of the cost (within the Institute of Geological Sciences) of manual production.

In his review of the familiar faunal range-diagram, Bursch categorized the commonly used kinds of diagram and quoted Moore's (1948, p. 324) point that the presentation of data, often painstakingly collected, in a single tabular manner may obscure the full significance of the results (Bursch 1950, pp. 479–484). This is probably because 'the *format* of the chart itself *dramatizes whichever viewpoint* is being used' (McLean 1972, p. 1). Though highly desirable, the production of several diagrams from the same data has never been fully practised perhaps because of the time-consuming nature of the work which is in itself not strictly palaeontological. Automatic data-processing methods are an obvious solution, for example McLean (1972, p. 5) devised a semi-automatic system using relatively cheap card-punch and card-sorting equipment.

By mid-1972 the Institute of Geological Sciences Computer Unit had written a package of computer programs in 1130 Fortran for the display of cartographic and lithostratigraphic data on the commonly used IBM 1130 computer configuration. It was then decided to write programs to produce the conventional faunal rangediagrams and link them with part of the larger package which drew ornamented lithological sections. At the same time dictionaries were established containing full fossil names and the appropriate type-setting instructions so that a copy of the specieslist for a particular diagram could be automatically punched on paper tape to be fed into a phototypesetter which can produce, if required, a correctly type-set and punctuated faunal list. This list, together with the diagram, results in the automatic production of a faunal range-diagram suitable for publication.

The major features of this palaeontological program package are here outlined (text-fig. 1) while full program listings may be obtained on request. Full details of the more generalized central part of the package are in Farmer and Johnson (*in press*).



TEXT-FIG. 1. Flow chart of the various program packages. L DATA, M DATA, and F DATA represent the input of lithological mineralogical and fossil data respectively. The various identifiers within rectangles represent the various program decks. CUF 11 and CUZ 88 produce only line-printer output; CUZ 84 and 85 may produce paper tape.

DATA INPUT

Data input (text-fig. 2) is short and simple. Lithological data (L DATA in text-fig. 1) consists of: the thickness of each successive lithological unit followed by the appropriate two-letter code corresponding to the desired lithological ornament punched on successive cards. For example, text-fig. 2A shows the entries on successive cards of a lithological sequence of (in descending order) 25·12 m of argillaceous limestone; 4·23 m of mudstone; 0·12 m of oolitic limestone; 1·56 m of clay. The whole entry occupies no more than the first nine columns of a standard 80-column punch card. At present some twenty-five ornaments are available while a zero entry results in blank space which may be ornamented manually if desired.

The fossil data (F DATA in text-fig. 1) or the mineral data (M DATA) are also presented in stratigraphical succession. Thus the first card of each stratigraphical sample (text-fig. 2B and C) states the number of species or minerals in the sample together with the upper and lower depth limits of the sample; and each subsequent card corresponds to each of the species or minerals in these samples. The species or minerals are not recorded by name but are given a code number (occupying the first four columns of the punch card) which is followed, in the case of species, by a simple (1-4) abundance code corresponding to 'present', 'fairly common', 'common', and 'very common' (text-fig. 2B). A zero is entered where the occurrence is doubtful. For example, text-fig. 2B shows the entries on successive cards of the first three species (code numbers, 4, 3, and 56) of twelve species determined from a depth range of 17.52-17.92 m, which are estimated as being present, very common and possibly occurring respectively.

The abundance code is the only difference between the fossil and mineral data input formats. This is because the mineral 'abundance' may be in the form of percentages (text-fig. 2c) and so one extra column is required on the data card. For example, text-fig. 2c shows the entries on successive cards of the three minerals (code numbers 1, 4, and 5) of a sample at 11.45 m depth which have been found by analysis to constitute 85%, 2%, and 10% of the rock. Percentage fossil data can, of course, be input on the M DATA format, while the replacement of abundance codes by equivalent, arbitrary percentage values would enable semiquantitative lithological and/or faunal data to be displayed alongside quantitative data. It is therefore possible to combine lithostratigraphical and biostratigraphical data on the same diagram. It will be seen then that the bulk of the data, whether in L DATA or M DATA format, occupies no more than the first seven columns of a standard data card.

Dictionaries giving the full fossil name and corresponding number code are permanently stored by accession order and by taxonomic order on punch cards (text-fig. 2D) as well as on a magnetic disc. It is simple to insert a new card when a name has to be changed or added to the list or to shuffle the deck of cards when the taxonomic order has to be changed.

A third kind of dictionary entry will be seen between the code number and the fossil name (text-fig. 2D). This is a letter code corresponding to convenient groupings, e.g. B = brachiopod, BR = rhynchonellacean brachiopod. This code enables the computer rapidly to break down large lists of species into meaningful sub-groups if desired.

In addition to the code number and full fossil name, type-setting symbols are inserted (text-fig. 2D) so that the output will be in italic or roman type and have upper

A lithological data input	B fossil data input	C mineralogical data input
12345678901234567890	12345678901234567890	12345678901234567890
25.12AL	12 17.52 17.92	3 11.45 11.45
4 . 2 3 M U	4 1	1 85
0.120L	3 4	4 2
1.56CL	56 0	5 10
	D dictionary input	

12345678901234567890123456789012345678901234567890123456789012345678901234567890

224 BR£/@R%HACTORHYNCHIA OBSOLETA #@((D%AVIDSON /NON #@S%OWERBY)

TEXT-FIG. 2A-D. Each row of data represents the left-hand side of one 80-column data card and shows the entries in their correct columns (as indicated by the italicized numbers) to produce the four different kinds of input.

MIDDLE JURASSIC MACROFOSSILS IN ACCESSION ORDER

0 brKallirhynchia sp.	PLANTAE
1 brKallirhynchia superba S.S.Buckman	
2 brRhynchonelloidella sp.	428 hSolenopora jurassica Nicholson
3 brRhynchonelloidella smithi (Davidson)	427 hSolenopora sp.
4 brRhynchonelloidella smithi crassa Muir-Wood	563 h'Solenopora' sp.
5 brRhynchonelloidella wattonensis Muir-Wood	426 halgae [frags]
6btsAvonothyris sp. nov. A	430lgnwood [frags]
7btsTubithyris sp.	137Ignlignite [frags]
8btsWattonithyris sp.	
9btsWattonithyris cf. fullonica Muir-Wood	PORIFERA
10btsWattonithyris cf. midfordensis Muir-Wood	
11btlOrnithella sp.	423 s'Peronidella pistilliformis' Lamouroux
12bt/Ornithella bathonica (Rollier)	424 s'Cliona' sp.
13btIOrnithella bathonica bathiensis (Rollier)	425 ssponge [frags]
14btIOrnithella pupa Muir-Wood	
15btlRugitela sp.	ANTHOZOA
16btlRugitela cadomensis (Deslongchamps)	
17 atHolzbergia sp.	188 scCalamophyllia sp.
18 atHolzbergia schwandorfensis (Arkell)	176 scChomatoseris hemisphericus (Milne Edwards & Haime)
19 atMorrisiceras sp.	177 scChomatoseris orbulites (Lamouroux)
20 atMorrisiceras comma (S.S.Buckman)	178 scChomatoseris porpites (Wm. Smith)
21 at <i>Morrisiceras krumbecki</i> Arkell	175 scChomatoseris sp.
22 atMorrisiceras morrisi (Oppel)	181 scCladophyllia babeana (d'Orbigny)
23 at <i>Morrisiceras sphaera</i> S. S. Buckman	180 scCladophyllia sp.
24 atMorrisiceras fornicatum (S.S.Buckman)	187 scConvexastrea sp.
25 at <i>Morrisiceras skipnum</i> S. S. Buckman	195 sc <i>Dimorpharaea defranciana</i> (Michelin)
26 at <i>Morrisiceras korustes</i> S.S.Buckman	199 scEwardsomeandra vermicularis Milne Edwards & Haime
27 azProcerites sp.	198 scEwardsomeandra sp.
28 azProcerites progracilis Cox & Arkell	174 scMontlivaltia sp.
29 an Procymatoceras baberi (Morris & Lycett)	196 scThamnasteria neptuni (d'Orbigny)
30 atTulites sp.	197 scThamnasteria terquemi Milne Edwards & Haime
31 atTulites subcontractus (Morris & Lycett)	194 scThamnasteria sp.

TEXT-FIG. 3. Output of fossil dictionary in accession order (to the left) and in taxonomic order (to the right) at 30.9.72. The list has been reduced in scale to the smallest possible size available.

or lower-case letters. The typesetter is fed by tape produced from the dictionaries held on the magnetic disc and produces correctly type-set and punctuated lists (textfig. 3) which it can reduce (or enlarge if desired) so that a large list can be copied at a convenient size. The input characters for typesetter instruction have been carefully chosen so that in other forms of dictionary output (e.g. the fast lineprinter output from the computer or the tape-typewriter print of the paper-tape contents) they will not be printed. These other forms of dictionary lists are then much easier to read than they would be were the redundant type-setting instructions retained. For example, text-fig. 2D shows the dictionary entries for a species (code number 224) of a rhynchonellacean brachiopod (BR). The typesetting instructions for upper and lowercase @ and $\frac{9}{0}$ precede the appropriate letters and the symbols # and / precede the text to be printed in roman or italic print. The symbol £ instructs the typesetter to delete all the entries to its left if required.

THE PROGRAMS AND THEIR OUTPUT

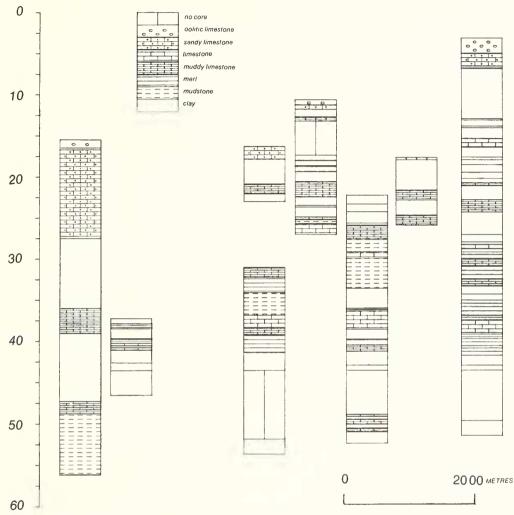
The programs available within the package are labelled (text-fig. 1) by their program identifiers. CUC 90 plots a series of lithological sections side by side in specified horizontal and vertical relative positions (text-fig. 4) thus providing a skeleton correlation diagram. CUC 70 plots individual lithological sections in the correct vertical position relative to plots of stratigraphical range data. Both programs provide

556

MIDDLE JURASSIC MACROFOSSILS IN MEMOIR ORDER

DEPTH IN METRES

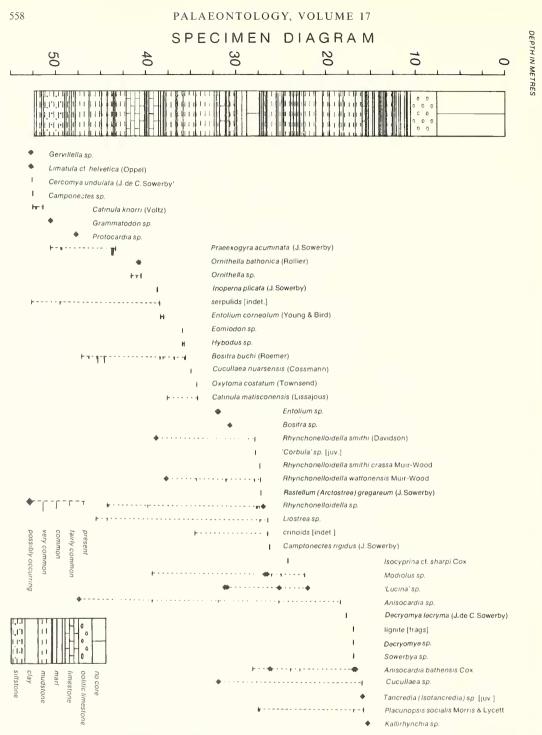




TEXT-FIG. 4. Skeleton correlation diagram as output by CUC 90 in which the sections are correctly positioned stratigraphically and geographically. Labels and tie-lines may be added manually.

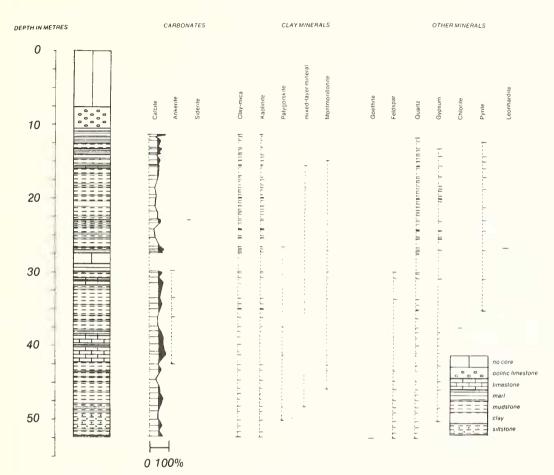
a separate list of those horizons which are too thin to ornament at the chosen scale. CUZ 10 and CUF 10 read M DATA and F DATA respectively and store them on a magnetic disc for accession by the remaining programs. Thus CUF 11 prints out a check-list of the M DATA and F DATA stored by CUZ 10 and CUF 10, and CUZ 88 prints out, via the dictionaries, the full taxonomic name of all the different minerals or species stored by CUZ 10 and CUF 10.

CUZ 12 and CUF 12 deduce the stratigraphic range of each mineral or fossil stored by CUZ 10 and CUF 10 and plot range and abundance by first occurrence or last occurrence (text-fig. 5) or by either of those within designated sub-groups (text-fig. 6). It will be seen that the horizontal mark (which is proportional in length to species



TEXT-FIG. 5. Specimen range-diagram as output by CUZ 85 of last occurrence of Middle Jurassic macrofossils from a borehole near Bath.

SPECIMEN DIAGRAM



TEXT-FIG. 6. Specimen range-diagram as output by CUZ 12 showing the grouping of minerals. Calcite (shown manually ornamented above the 50% level) was determined quantitatively by wet analysis and this was used as an internal standard for calibrating the peak heights of the X-ray diffractograms. The analysis was not fully comprehensive.

abundance) enables every species occurrence to be localized. Where occurrence is from a range of depth (e.g. when fossils are recorded from 'Bed X') the horizontal mark becomes 'enlarged' to a box whose height corresponds to the range in depth and whose width corresponds to the abundance (e.g. in MK 16 on text-fig. 7). The code number of each fossil or mineral is plotted for identification but use of program CUZ 85 results in the same plots being produced together with a paper-tape list, in the correct order, of the full fossil names obtained from the appropriate dictionary corresponding to the code numbers on the plot. This paper-tape when fed through the phototypesetter produces a correctly typeset list which may then be affixed to the diagram in preparation for publication. CUZ 84 produces a paper-tape in the same way as CUZ 85 but plots the range and abundance data in fixed-order formats, e.g.

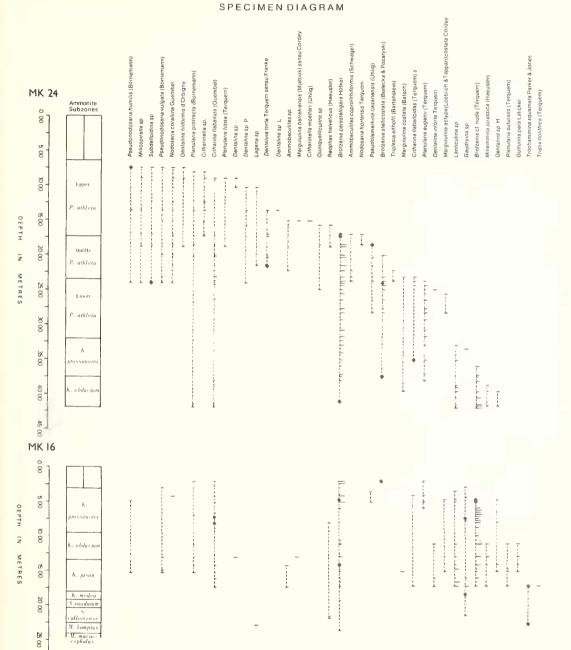
---- Verneuilinoides tryphera Loeblich & Tappan Danteline cuneiformis Terquem & Berthelin Lenticuline plebera (Terquem & Berthelin) --- f Ammobaculites agglutinans (d'Orbigny) Merginuline ectype(Loeblich & Tappan) ---- Frondiculeria franconica (Guembel) Opthelmidium stuilense (Pealzow) Dentaline alf filiformis d'Orbigny ---- 1 Lenticulina major (Bornemann) --+--+ Foguttuline liassica (Strickland) ----- Dentalina cf. filiformis d'Orbigny . 11. 1. L. ---- 1. 1. ---- Tenticulina muensien (Roemer) Vaginulina contracta (Terquem) ----- (Guembel) r - - - - Marginulina glabra (d'Orbigny) ------ Terqulina leavissime (Terquem) Inguline nodosarie (Terquem) ht immediate the standard st ----- Nodosaria opalini Bartenstejn 1 1--1 Dentatina guembeli Schwager Nodoserie metensis Terquem → -1 Lenticulina subalate (Reuss) ---r --r 1 T 1 Spirilline infime (Strickland) Denteline turgida Schwager ------ To ------ Oentalina vetusta d'Orbigny -1 TT-1 Sarecenaria triquetra (Guen Citherinella nikitini (Uhlig) Cornuspire liasina Terquem MK 24 --- 1 Lingulina cernue Terquem ----+ Dentelina torta Terquem Gaudryina? sp. 2 Lutze Ammonite Subzones -F 7-F - 1 Ophthalmidium sp 00 0 The standard second sec Dentaline sp E ---- Oentelinasp. M Dentalina sp. K Plenulerie sp. 5 00 1------++-ī Ť. Ī ------LL --- 1-5-- - - - - E ****** 1000 ---------Unper - L - - - - - - L -----.l. ----and the ŧ 1 P. athleta ļ, -L--1 +--------------the second secon ---------15 00 ----- 4- 6 11.1. DEPTH ŀ فالقانا والالانان والمتالية والمراكر والمعتر والمعارية والمعارية والمعارية والمعارية والمعارية والمعالية والمعارية والمعالية والمعارية والمعالية و and have ----È Ŀ 114 b Ļ ł -----------į -H----- - -Ŀ ţ ł ----E ł ł ŝ ALLING AND ALL HARA LU 20 00 Middle -------------ž E ÷ ----. The state has been as a second s ŧ ----------adama babili da ana ana s ------------------P. athlete i, and a state of the ----- 1-6-6-4 METRES Ē ----ŝ 25 00 لتتبط للتلاعية معاديات والمتعالفين والمتعال and the statement of the second Lower i and an an one of a state on the data of the P uthlut 30,00 κ. 35 OO F ŀ -----------40 00 K. obductu -----L-H È 45 00 MK 16 000 بأنباذا والارتداد الطار للتان متار لتنار والمرار ----50 1.14 ĸ. فاستعدت والالالا فالمالية والمتحاد والمرافعة ومتكرونهم DEPTH F----d--1644 rossouvr E ----10 00 ī abduct METRES ist 8 ---------i K. jason F 1 ÷ K. medea 20 00 i È S. calloviensi i i. Ë ķ 1. Lamptu 25 00 W. macro cephalus

TEXT-FIG. 7. Upper Jurassic foraminifera from two boreholes in Central England. The data of borehole MK 24, penetrating younger strata, have been arranged by last occurrence as output by CUZ 85. Data of borehole MK 16, penetrating older strata, have been arranged as output by CUZ 84 in the order discovered in MK 24. Ammonite subzones have been plotted instead of lithology. Species abundance key as in previous diagrams.

PALAEONTOLOGY, VOLUME 17

560

SPECIMEN DIAGRAM

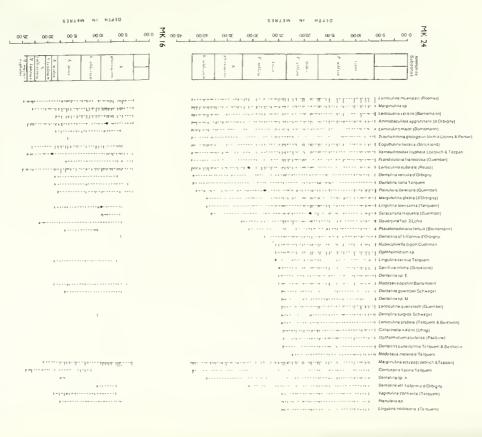


PENN: STRATIGRAPHICAL RANGE-DIAGRAMS

561



TEXT-FIG. 7. Upper Jurassic foraminitera from two boreholes in Central England. The data of borehole MK 24, penetrating younger strata, have been arranged by last occurrence as output by CUZ 85. Data of borehole MK 16, penetrating older strata, have been arranged as output by CUZ 84 in the order discovered in MK 24. Ammonite subzones have been plotted instead of lithology. Species abundance key as in previous diagrams.



Z3RT3M NI HT930 DEGTH IN METHES MK 16 K 00 S. 00.59 00.92 50.00 00.01 00.5 00 0 00 D 00.09 00 9£ 00 GE 00.9 00 Ok 00.5 00 52 00 DZ 2 P. ashle tipe Low-Up dzł n 10727 -ibdi 2 ••••••• PSRUG Miliospiralia ap Subdeflordine +p Pseudonodosa na sulgata (Both Nodosana corattina Guembel Dentalina liliformis d'Orbigny Planuiar+a profiacle (Bornemann) Cithainalia Ip Citharina Nebeliata (Guembel) Planularia Nosa (Tarquem) Denialina tp Dentalina an P Lagena tp Denialina toria Tarquem sentu Franka •-----Denisios (D.L. Ammobaculitat ap. Migginulna batiak anava (Mjatirus) i anav Cordey Cilharinalla moellarii (Unirg) Ovinguelocvina ap Reophae helvelicus (Heauster) ١١. ٢٩ Brolzerva parastelligara Holker Ammobacultas coprolibilormis (Schwagar) 0 ~ -1 Nodosene hortensis Terquem Pseudolamarkina rjaaarienii 1 (Uhlig) Brotzenia aleri-coartila (Bislecka & Pozanyski) Puplesia atthotti (Bartenstalo) Marginulina costata (Batsch) •-----• Criterine Nebelloides (Terguern) 1 Planufatia eugenit (Tsirquem) Dentalina inforta Tarquem . Marginulina ectypajLoeolich &Tappanjcostats Corday Lenticulna tp Gaudhyina ip ه.... ۱۰۰۰۰۱ ۱ ۱۹۰۱ میلید با بلار Broizenia cl. nuda (Cerquem) Milammina (urastinta (Hansila)) Dentalma (p. H. Planulatia tuturaka (Terguem) Gurbrine pere Lai-cher Trochammine Iguamate Parket & Jones Tratic opicifica (Tarquem)

PENN: STRATIGRAPHICAL RANGE-DIAGRAMS SPECIMEN DIAGRAM

560

PALAEONTOLOGY, VOLUME 17

SPECIMEN DIAGRAM